

# Lattice Results on Behavior of Quarkonia In a Gluonic Plasma

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- Lattice study of 1S and 1P charmonia in plasma
- Behavior of charmonia moving in the heatbath
- Preliminary results on bottomonia

# $J/\psi$ as probe of deconfinement

T. Matsui & H. Satz, Phys. Lett. B178, 416 ('86)

- Screening in plasma  $\implies$  reduced binding between  $\bar{c}c$

Solving Schrödinger Eqn. with lattice potential  
 $\eta_c, J/\psi$  dissolve by  $\approx 1.1T_c$

Karsch and Satz '91; Digal *et al.* '01; Wong '02

## *Issue of the lattice potential*

Jahn & Philipsen, PRD 70(2004) 074504; Kaczmarek & Zantow, hep-lat/0506019.

- Collision with hot gluons  $\implies$  gradual broadening

Below  $T_c$  pion gas  $\rightarrow$  soft gluons,  $|p| \sim 0.6T$

Thermalized gluon gas  $\rightarrow$  hard gluons,  $|p| \sim 3T$

Kharzeev & Satz, Phys. Lett. B334, 155 (1994)

- Direct lattice study of mesonic correlators:

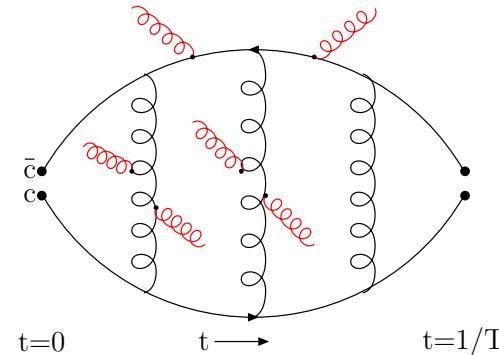
$J/\psi$  survives in gluonic plasma till  $\gtrsim 2T_c$

Datta *et al* Nucl. Phys.(PS) 119(2003) 487; PRD 69(2004) 094507  
Asakawa & Hatsuda, PRL 92 (2004) 012001; T. Umeda *etal*, Eur. P.J. C39S1(2005)9

Direct study on lattice

Matsubara correlator

$$G_H(\tau, \vec{p}, T) = \sum_{\vec{r}} e^{i\vec{p} \cdot \vec{r}} \langle J_H(\tau, \vec{r}) J_H(0, \vec{0}) \rangle_T$$



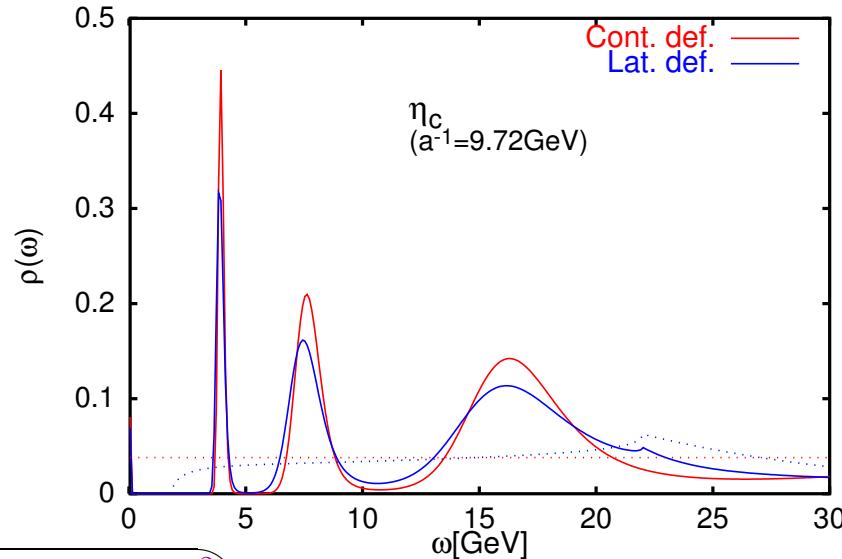
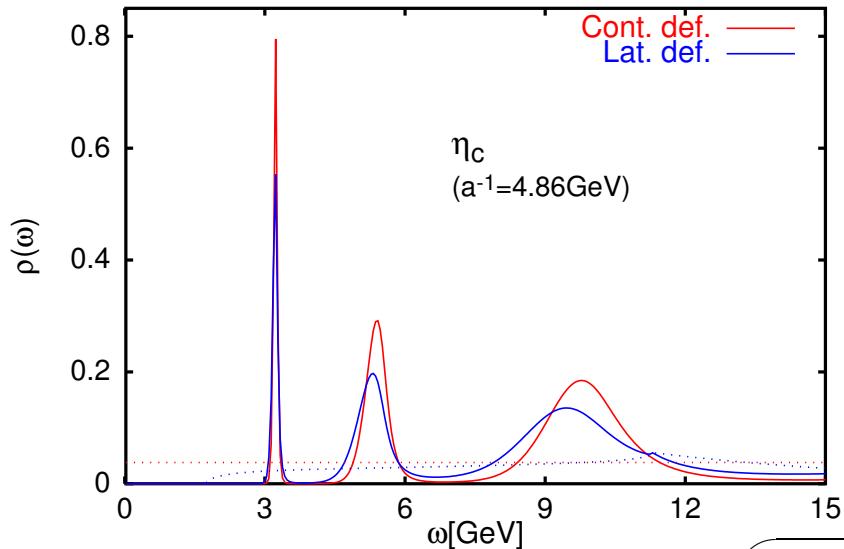
$\bar{c}c$	$^3P_0$	$\chi_{c0}$
$\bar{c}\gamma_5 c$	$^1S_0$	$\eta_c$
$\bar{c}\gamma_i c$	$^3S_1$	$J/\psi$
$\bar{c}\gamma_i\gamma_5 c$	$^3P_1$	$\chi_{c1}$

$$G_H(\tau, T) = \int_0^\infty d\omega \sigma_H(\omega, T) \frac{\cosh(\omega(\tau - 1/(2T)))}{\sinh(\omega/(2T))}$$

Inversion using **Maximum Entropy Method**

High energy structure of  $\sigma_H(\omega, T)$  as prior information.

Jarrel & Gubernatis, Phys. Rept. 269, 133 (1996)  
Asakawa *et al.*, Prog. Part. Nucl. Phys. 46, 459 (2001)



$$\rho(\omega) = \sigma(\omega)/\omega^2$$

Nontrivial structure at high  $\omega$

shifts  $\sim a^{-1}$

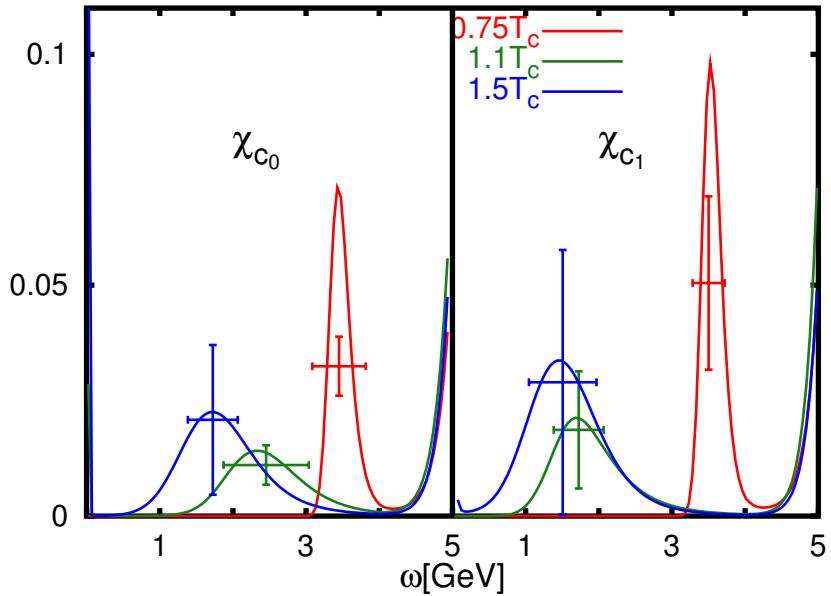
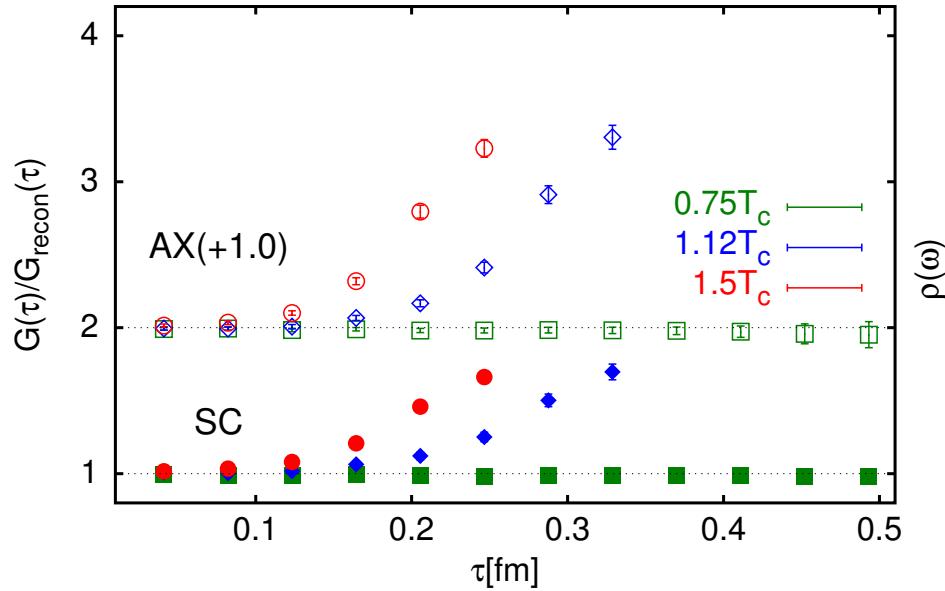
- Supply high  $\omega$  peak structure as prior information

Reconstructed correlator

$$G_{\text{recon}, T^*}(\tau, T) = \int d\omega \sigma(\omega, T^*) K(\omega, \tau, T)$$

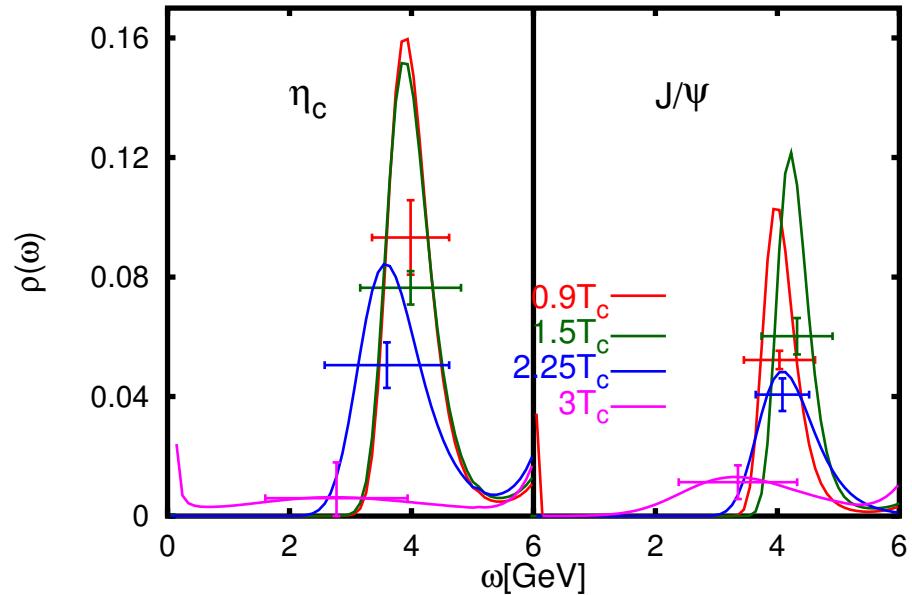
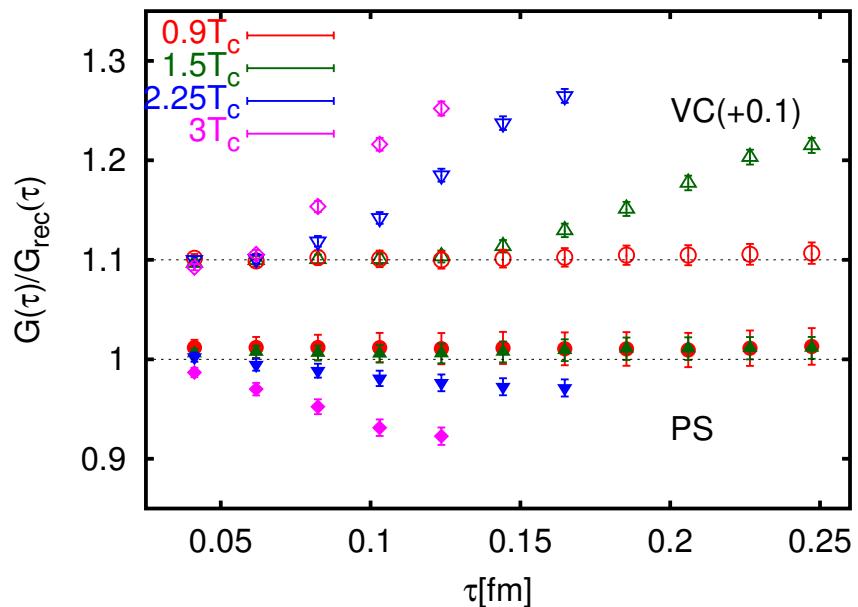
Compare with  $G(\tau, T)$

1P state undergo serious system modification already at 1.1  $T_c$



The correlator modification will be consistent with the dissolution of the state at  $T_c$

Spectral function supports the conclusion



### 1S States survive upto $2.25 T_c$

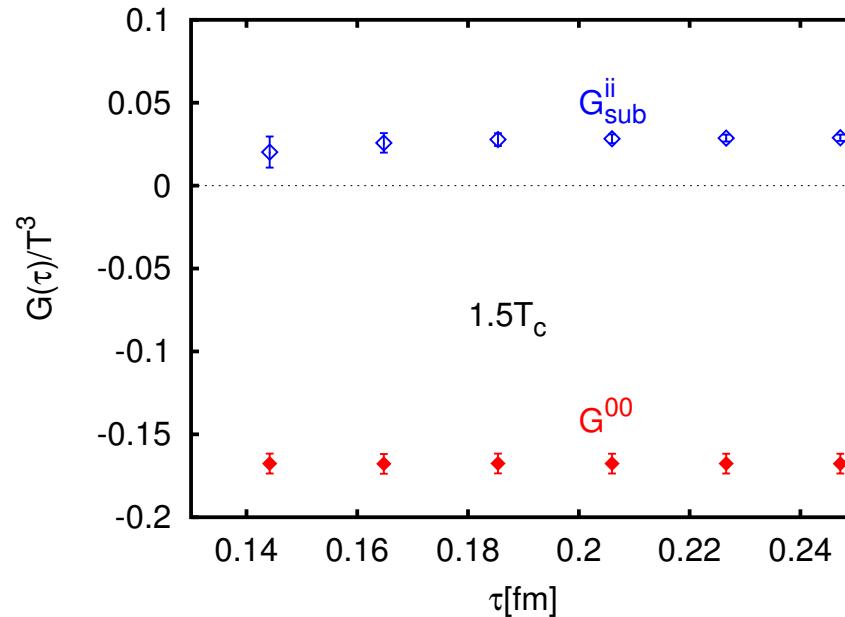
- $\eta_c$  shows no change upto  $1.5 T_c$
- Weakening (and possibly broadening) at  $2.25 T_c$
- No significant resonance seen at  $3 T_c$
- $J/\psi$  shows no weakening upto  $1.5 T_c$
- Weakening (and possibly broadening) at  $2.25 T_c$
- No significant resonance seen at  $3 T_c$

S. Datta *et al*, Phys. Rev. D 69 (2004) 094507

Temperature modification of the vector correlator:  
related to transport coefficients?

Petreczky & Teany, hep-lat/0507318; Petreczky *etal*, hep-lat/0510021

$$\sigma_{\text{sub}}^{ii}(\omega, T) \sim \chi_s(T) \omega \frac{T}{\pi M} \frac{\eta}{\omega^2 + \eta^2}$$



$$\sigma^0 0(\tau)/T^3 = \chi_s(T) \omega \delta(\omega)$$

$M/T \approx 5.2 \pm 0.5$  too large

What happens when  $J/\psi$  is moving in the heatbath frame?

Moving  $J/\psi$  sees more energetic gluons  
More serious modifications?

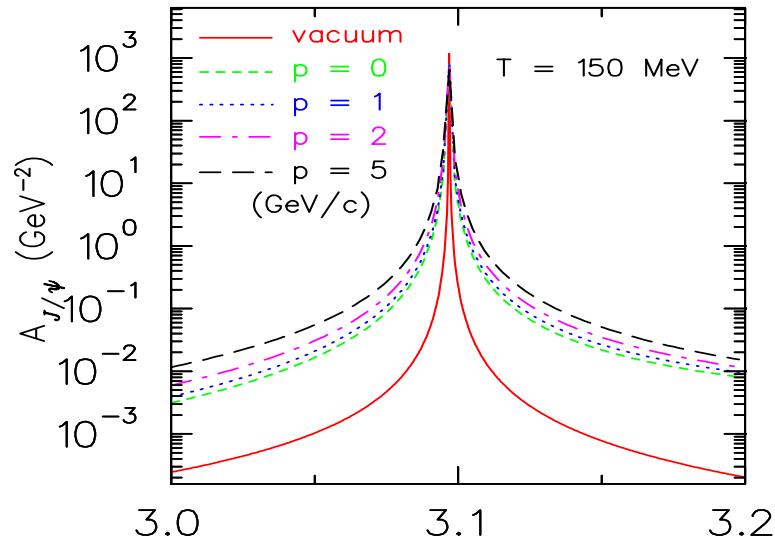
For Coulombic quarkonium  $\Phi$ :  $\sigma_{g\Phi} \sim (k - \epsilon_0)^{3/2}$

When  $\Phi$  has momentum  $p$ :  $k \rightarrow k(\sqrt{1 + p^2/m_\Phi^2} + p/m_\Phi)$

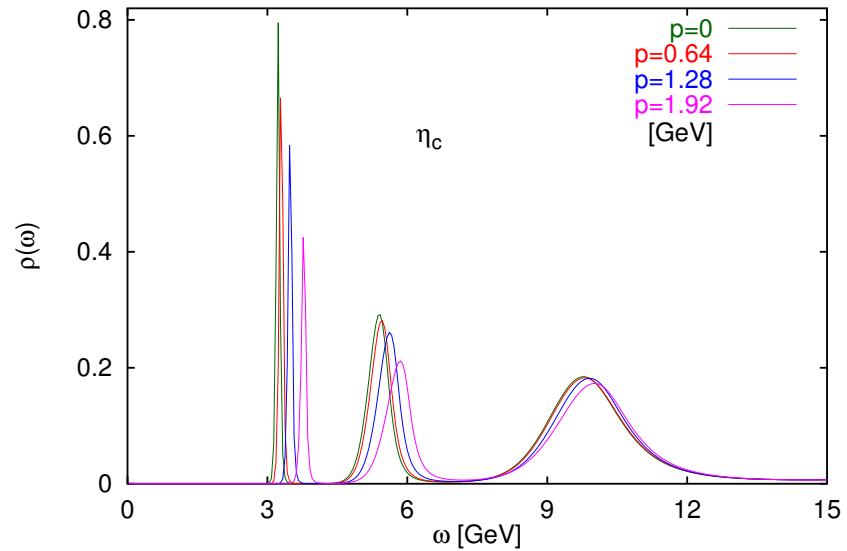
Model calculations *in hadronic phase*:

Broadening of  $J/\psi$  with momentum

Haglin and Gale, PRD 63,065201

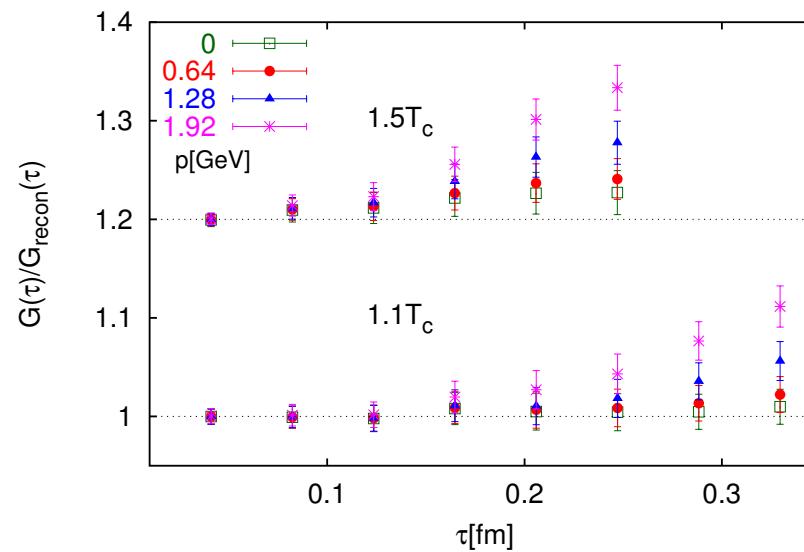
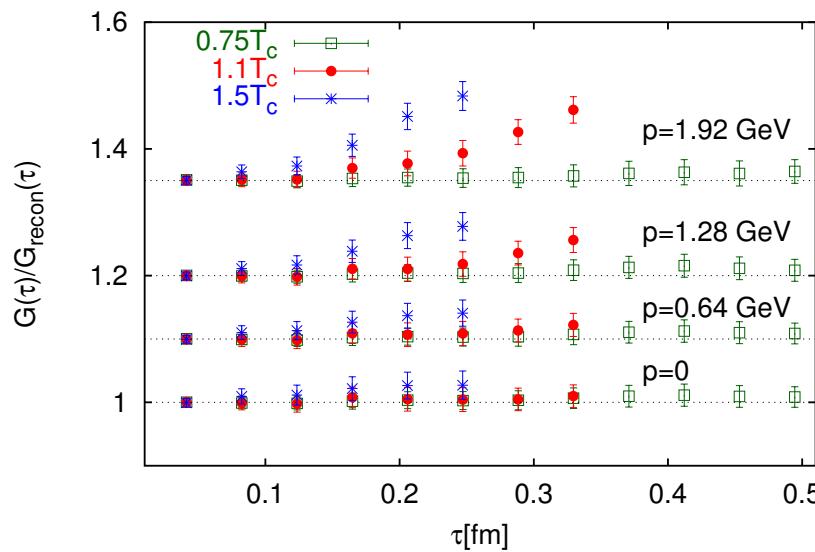


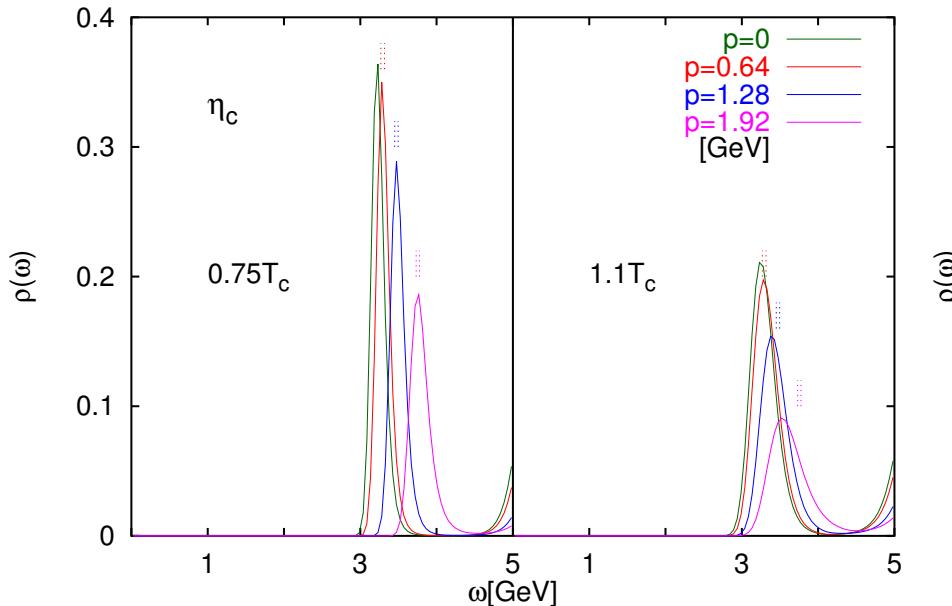
*Preliminary results* Datta *et al.*, hep-lat/0409147



$$G_{\text{recon}}(T, \vec{p})$$

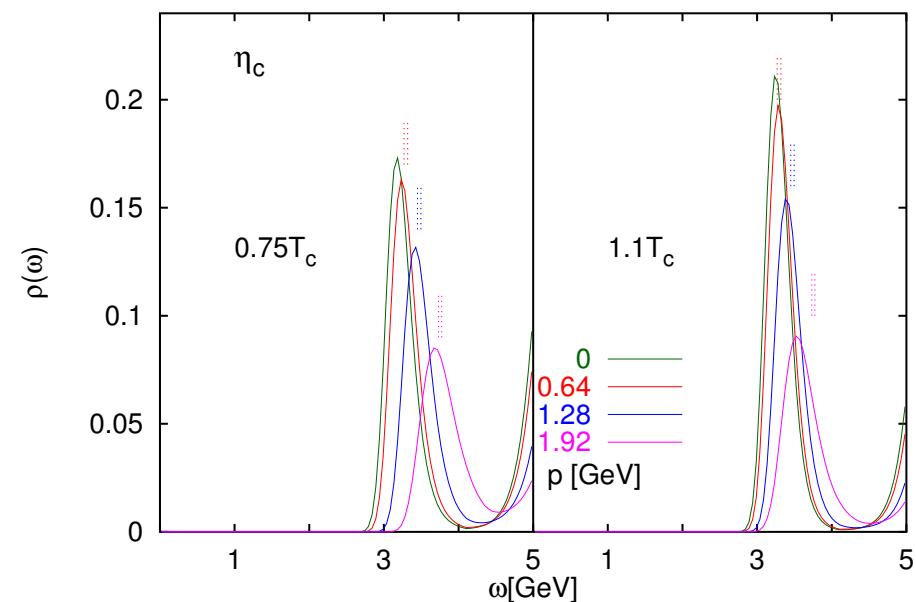
$$= \int d\omega \sigma(\omega, \vec{p}, 0.75T_c) K(\omega, \tau, T)$$





Thermal broadening?

Change of dispersion reln.?



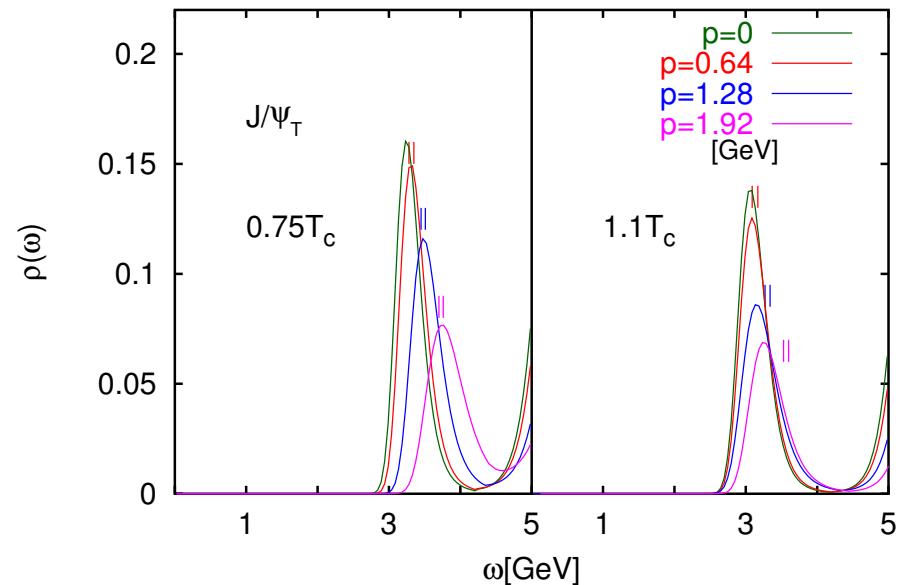
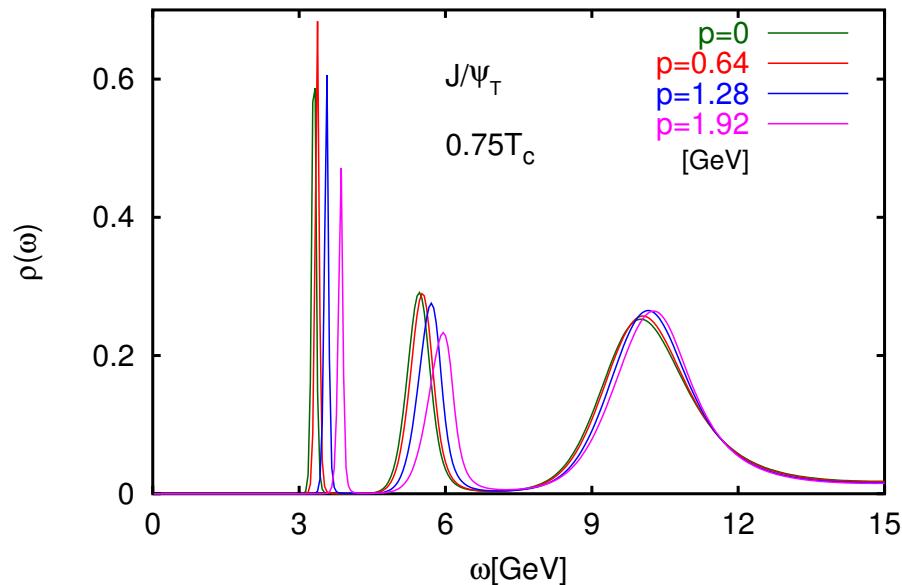
Use same data points

Change in dispersion relation

Will affect screening mass

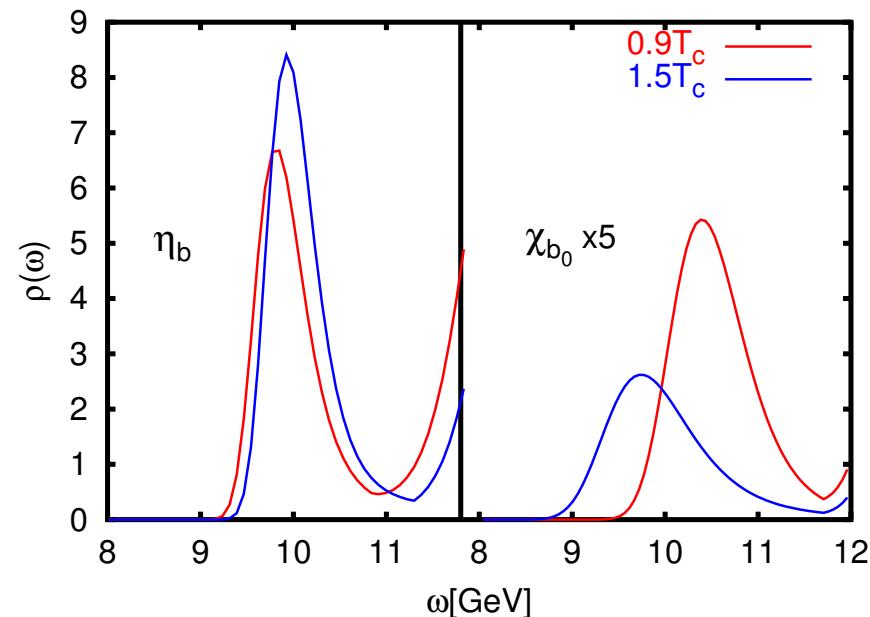
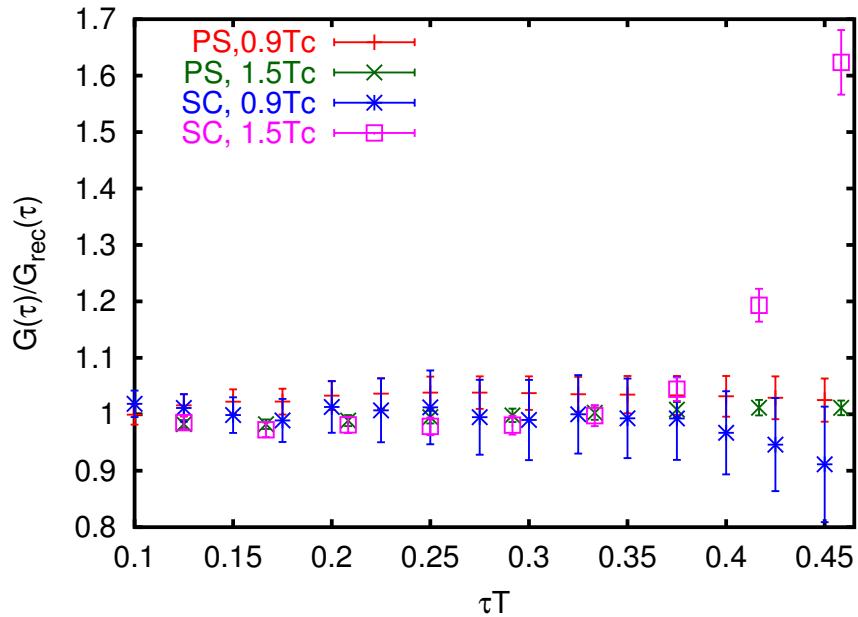
*Significant resonance till high momentum*

Similar results seen for  $J/\psi$



Preliminary results for Bottomonia:

$a^{-1} = 9.72$  GeV : lattice artifacts more severe



Consistent with the results of K. Petrov *et al.*, hep-lat/0509138

- Serious system modification for  $\chi_c$  states,  
possibly dissolution, after deconfinement
- 1S states survive in gluonic plasma
- Little reduction of strength seen upto  $1.5 T_c$
- Dissolution at higher temperatures
  - Gradual broadening?*
  - Sudden disappearance?*
- *very preliminary* Attempt to extract transport
- Charmonia moving w.r.to heatbath
  - Have more serious modifications
  - Significant 1S states till high momenta
- Preliminary results for bottomonia:
  - 1P states show significant system modification
  - Already at  $1.5 T_c$